AP Biology

Unit 2.3 – Homeostasis Mechanisms

Notes & Practice Quiz

Contents

Section 1 – Homeostasis Principles

1.1 – What is Homeostasis?

As discussed in unit 1, the environment is constantly changing and organisms must adjust to these changing conditions or they may not survive. The process of maintaining optimal cell conditions is known as **homeostasis** and any mechanism used to do such is a **homeostatic mechanism**.

1.2 – What are some conditions requiring homeostasis?

Growth and maintaining body mass are critical to survival but reproduction is also vital to the species. Organisms must meet both requirements to be successful and have adapted many strategies to perform both tasks during their lives. Acquiring materials & energy requires adaptations to do so at key times and from optimal resources. While surviving external or internal attacks is necessary to survive, it is maintaining or returning back to normal conditions under these times of stress where homeostatic mechanisms must be employed. Finally, normal cell division patterns must be followed during times of development for the organism to mature correctly and also to avoid cancer which is any form of abnormal cell division.

1.3 – How does negative feedback maintain homeostasis?

A **feedback mechanism** is any process where a stimulus that is part of the feedback pathway triggers a response in that pathway. All feedback pathways also rely on some "set-point" desired by cells or required for a specific process, both pre-determined by our DNA. **Negative feedback** is when increasing amounts of a stimulus trigger a response that decreases the stimulus. A classic example is blood sugar regulation: Rising levels of sugars in the blood stimulate the release of the hormone insulin; insulin causes absorption of glucose out of the blood and into storage cells, thereby causing the level of blood sugar to drop. Negative feedback is the most common type of pathway and it will be seen in many examples throughout the remainder of these notes.

1.4 – How does positive feedback maintain homeostasis?

Positive feedback is when increasing amounts of a stimulus trigger a response to increase the stimulus further. A classic example is uterus contractions during childbirth: Rising levels of the hormone oxytocin stimulate uterus muscle contractions to push the baby through the birth canal. These contractions promote the release of even more oxytocin, leading to more intense muscle contractions, eventually leading to the birth of the child. Positive feedback is a less common type of pathway but it will be seen in some examples throughout the remainder of these notes.

Section 2 – Homeostasis during development & Growth

2.1 – How does a zygote begin to differentiate?

Development is the time period from fertilization to the point of performing most life functions independently. In plants this is from fertilization to a germinating seed but in animals this is from fertilization to birth, hatching, etc. How do we generally end up normal functioning organisms from just a single cell? In a fertilized cell there are your genetic instructions as DNA but also some other key proteins from the mother's egg cell called **cytoplasmic determinants**. These proteins in the egg cell are distributed asymmetrically based on their densities and affinities for certain regions in the cell. Once fertilized, the zygote will divide and the molecules will be of different concentrations in the 2-celled embryo. This uneven distribution is called **asymmetric distribution** and leads these early cells into **differentiation**, the path to becoming distinctly fated cell types based on how the cytoplasmic determinant proteins interact with the cell's DNA. Draw the diagram on p. 368 to illustrate this concept.

2.2 – How do specialized cell types arise?

Observing any multicellular organism begs the question of how all those different looking & functioning cells came from just a single cell. As a cell's unique set of cytoplasmic determinants interact differently with the same exact DNA in all cells, unique RNA's & proteins are produced in each new cell. The developing cells all remain in a ball of cells, in contact with nearby cells but out of reach of other cells. The molecules in each cell may diffuse or be actively transported to other nearby cells and their developmental interactions & consequences are called **inductive signaling**. For example, nerve tissue germ cells all resides at the top/dorsal region of a zygote whereas gastrointestinal tissue germ cells are towards the bottom. Their interactions will be different since they contact different cells but all nerve tissue cells for example will have many common interactions, leading to their similarities as mature cells.

2.3 – How is cell growth controlled?

Why aren't we just one large cell with specialized regions instead of trillions of cells? Small cells have more surface area per amount of volume which is critical for importing and exporting materials in a timely fashion. As a cell divides by mitosis during all growth, regulators called **growth factors** keep it dividing & growing until cells/tissues are their ideal size. Other signals promote cell death or inhibit further growth/division. Most tissues exhibit **density-dependent inhibition** whereby anchoring with other cells allows negative feedback by chemical signaling. A special form of programmed cell death called **apoptosis** leads to cell death during specific times. In animal development, your fingers develop inside a layer of protective tissue that dies off by apoptosis to expose the fingers once fully developed. In plants, apoptosis is responsible for dormancy during winter, including the death of deciduous leaves.

2.4 – What are the consequences of abnormal growth & development?

Deformities, death, diseases & disorders can occur if any errors occur during development or growth. If a defective gene codes for an incorrect amount of a regulatory molecule, the cell may be defective. **Cancers** arise when cells divide uncontrollably from incorrect amounts of regulator molecules, leading to tumors that can disrupt the functioning of other cells. Embryos experimented on show us that changing the amount of regulatory molecules or the locations of cells can lead to frogs with both ends as tails but no head for example. Genes that control the formation of the body plan in animals, called **HOX genes**, undergo mutations very slowly leading to gradual changes through evolutionary history; however, a large mutation in these genes or unfavorable combination from 2 parents is the leading cause of miscarriages because body plan formation is so critical during development.

Section 3 – Biorhythms, Triggers & Behaviors

3.1 – What is a circadian rhythm & how is it controlled?

A biorhythm, also called a **circadian rhythm**, is any physiological pattern attuned to a specific time or period. Most circadian rhythms are linked to light triggering the release of hormones. Sleep cycles are an example of how special nerve cells are triggered by their time in contact with light. The amount of light triggers a certain level of the sleep hormones melatonin & serotonin that cause sleepiness. Animal reproductive cycles also follow a distinct pattern. A set point within the nervous system triggers the release of hormones during certain times, assuring all phases of pregnancy & rearing offspring are at the optimum time for the species.

Many plants exhibit a biorhythm called **photoperiodism** that controls flowering. In photoperiodism, a certain ratio of dark/light triggers normal growth patterns; however, a change in this dark/light pattern during certain times of the year triggers flowering. **Short-day plants** flower during times when the amount of darkness is more than some set value, usually in autumn. **Long-day plants** flower during times when the amount of darkness is less than some set value, usually in the summer. These biorhythms help maintain homeostasis by assuring certain processes only occur at set times, making the most of growing & reproducing during times of high energy availability.

3.2 – What are some significant responses in plants?

Plants respond to the materials they need & compete over most: light & water. Light triggers numerous responses in plants mainly by triggering the release of the hormone **auxin** that stimulates growth of all types. Water also triggers growth and flowering of many plant species, especially in areas where it is scarce like deserts. Water causes plant cells to swell by osmosis which is a major mechanism of directed plant growth towards light (phototropism) as certain cells absorb more or less water; it causes different cell volume & thus bending of the stem (see p.825 for diagram).

3.3 – How do animals respond to environmental stimuli?

Animals have distinct behaviors that are sometimes **innate** (genetic) or **learned** (molded by interactions with the environment). Why do those crazy bugs fly into bug zappers anyway? Even though it will lead to their doom, it is most likely coming from an innate desire to be near a light source called **positive phototaxis**. Some other innate behavior examples include migration patterns, crying babies, certain courtship rituals and hibernation (**torpor**). Despite their differences, they all have common roots in evolution that will somehow increase their reproductive or survival success…even if a few die in a bug zapper!

Learned behaviors have a genetic component but mainly develop by trial and error or mimicking others. Solitary animals learn some behaviors by trial and error such as what to eat & where to hide offspring. Unfortunately the errors can sometimes lead to deaths but that's survival of the fittest. Social animals also use trial and error but the advent of mimicking family members is frequently seen, as we toddlers began to mimic our parents or baby elephants learn to roll in mud for natural sunblock. Some extreme cases of behavior called **altruism** actually increase the chance of death of certain individuals as they sacrifice themselves for the colony/family. The theory is that since the population will survive, large families risk and even purposefully produce some individuals to die to ensure the survival of the rest of their family. Animals who take on the role of "watchmen" on patrol have a much higher chance of being eaten but their family will survive by hearing a warning call. One very intense termite species has a group of soldier termites that contain toxic levels of chemicals that can explode. Their body exploding kills themselves but also many enemies, saving the colony!

Section 4 – Defenses against Pathogens

4.1 – What forms of immunity are there?

Pathogens and parasites are constantly evolving mechanisms to invade other organisms for their resources. Although not completely effective, organisms display a wide variety of barrier & internal defenses to maintain homeostasis. **Innate** or **non-specific defenses** have evolved to fight a variety of pathogens based on being attacked by them for long periods of evolutionary time. These defenses target any material detected as foreign. **Acquired** or **specific defenses** arise after being exposed to a particular foreign material allows memory cells to develop & destroy the material faster if exposed again.

4.2 – What are the first line of defense systems?

In animals, skin and other barrier structures provide physical protection while chemicals like saliva, sweat, toxins & acids provide an initial chemical barrier. Plants also produce toxins and many chemicals that inhibit entry past outer tissues. Many plants even secrete chemicals that attract organisms that will harm an herbivore eating it. Animals have innate immunity that targets pathogens if they breach the outer defenses also. One example is the inflammatory response: A site of penetration will release chemicals called **cytokines** & **histamines** that signal injury has occurred. Blood vessels dilate, allowing platelets to squeeze through blood vessels & seal the wound. Also arriving in the blood are immune cells called **macrophages** which will engulf any pathogens by phagocytosis. Special proteins called **interferons** disrupt viruses from spreading to other cells and **complement proteins** can cause cellular pathogens to lyse (burst).

4.3 –How are helper T Cells central to acquired immunity?

An **antigen** is any part of a foreign substance used to trigger an acquired immune response. Helper T cells constantly circulate looking for **antigen-presenting cells**, those that have isolated an antigen to present to a helper T cell for initiation of an acquired immune response. The **helper T cell** is activated once presented with the antigen and releases cytokines. **Cytokines** chemically signal the 2 acquired immunity cell types: Cytotoxic T cells & B cells. Draw figure 43.16 on p.941 showing this concept.

4.4 – How does the cell-mediated response fight pathogens?

Once activated by helper T cell cytokines, **cytotoxic T cells** target & destroy infected cells. They release chemicals called perforins that cause the cell to lyse and thus be destroyed. Before finishing its job, the cytotoxic T cell is stimulated to divide into memory cytotoxic T cells that will help target the same pathogen much faster if exposed again. Draw figure 43.17 on p.941 showing this concept.

4.5 – How does the humoral response fight pathogens?

Once activated by helper T cell cytokines, **B cells** secrete proteins called antibodies. **Antibodies** function by binding to the antigens on a pathogen and flagging them for destruction by macrophages and other phagocytic cells. Draw figure 43.19 on p.943 showing this concept. Before finishing its job, the B cell is stimulated to divide into memory B cells that will be able to secrete antibodies against the same pathogen much faster if exposed again.

Quiz Practice

1. Acquired Immunodeficiency Syndrome (AIDS) is caused by the HIV virus which targets & destroys Helper T cells. Which of the following is least likely to be affected in a person with AIDS.
    a. Their antibody levels
    b. Their inflammatory response
    c. Their cytokine production
    d. Their Cytotoxic T cell levels

2. The RAS-3 gene encodes an immune protein that can kill a wide range of bacteria. Its gene sequence is similar across domains & most animals, plants & fungi possess this gene and produce these proteins. Which statement best describes the rationale behind this finding?

    a. This specific form of immunity was passed down from a common ancestor.
    b. These proteins must be antibodies.
    c. Certain bacteria must have been pathogenic in a common ancestor and this innate immunity strategy was beneficial.
    d. All of these organisms developed a similar gene independently that provided a successful innate form of defense.

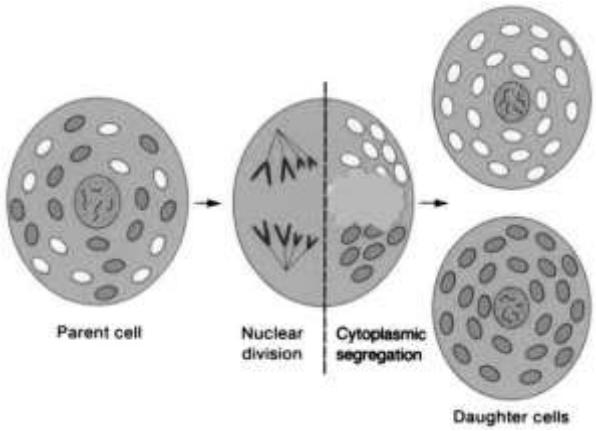
3. A person feels an illness coming on after having been sick already just about 1 month ago. She goes to the doctor, her antibody serum level is checked & compared to her test from the last time she was sick. Which of the following test results would make it likely that her symptoms will be similar to the previous one but shorter in duration?

    a. Her Helper T cell count will be the same as the previous test.
    b. Her antigen level will be higher than the previous test.
    c. Her Cytotoxic T cell count will be lower than the previous test.
    d. Her antibody level will be higher than the previous test.

4. Which is not a form of innate immunity?

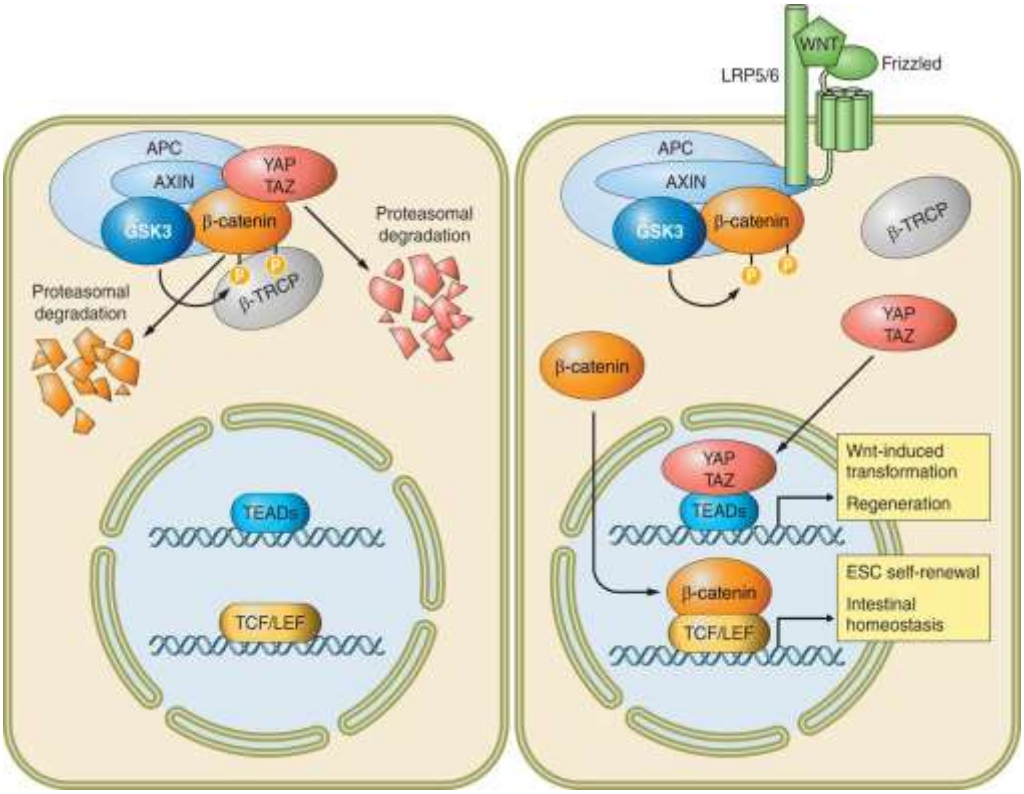
    a. Saliva
    b. Acids
    c. Histamines
    d. Antibodies

In identical twins a single egg is fertilized by a single sperm and then the zygote divides and splits apart as shown below instead of remaining attached to each other as usual. From there, the 2 zygotes will continue their embryo developments as usual.



5. Which statement best describes identical twins?

a. They always have the same DNA but it will be expressed differently, leading to slight variations in their phenotypes.
b. They always have different DNA but it will be expressed the same, leading to slight variations in their phenotypes.
c. They always have the same DNA that is expressed the same, leading to their identical phenotypes.
d. They always have different DNA that is expressed the same, leading to their identical phenotypes.



6. The diagram above shows 2 connected cells with different gene expression activities. Which explanation best describes the rise of these different gene expression activities?

a. The DNA in the cells is different.
b. The function of YAP TAZ in the cells is different.
c. Certain proteins are found in one cell but not the other.
d. The embryonic cytoplasmic determinants must have been identical in both cells.

7.

Mammalian milk contains antibodies that are produced by the mother's immune system and passed to offspring during feeding. Mammalian milk also contains a sugar (lactose) and may contain proteins (protein A, protein B, and casein), as indicated in the table.

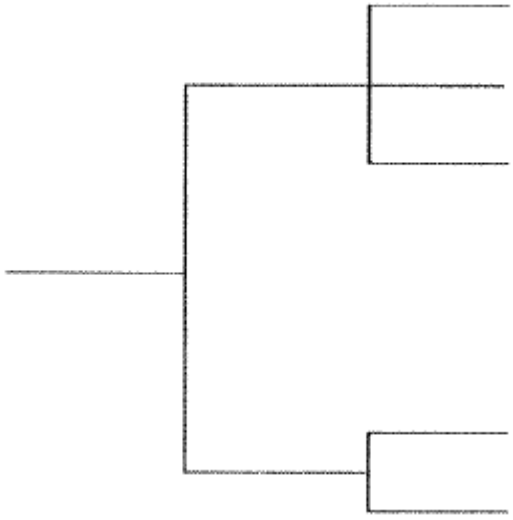
MILK COMPONENTS IN DIFFERENT MAMMALS

Character	Cat	Cow	Horse	Human	Pig
Lactose	+	+	+	+	+
Protein A	+	+	+	+	+
Protein B	–	+	+	–	+
Casein	–	+	+	–	+
+ indicates the presence of the character, and – indicates the absence of the character					

(a) Using the data in the table, **construct** a cladogram on the template provided to indicate the most likely evolutionary relationships among the different mammals. **Indicate** on the cladogram where each of the characters most likely arose in the evolutionary process, and **justify** the placement of the characters on the cladogram.

(b) **Describe** FOUR steps in the activation of the mother's specific immune response following exposure to a bacterial pathogen. **Predict** how the mother's immune response would differ upon a second exposure to the same bacterial pathogen a year later.

(c) **Predict** the most likely consequence for a nursing infant who is exposed to an intestinal bacterial pathogen (e.g., *Salmonella*) to which the mother was exposed three months earlier. **Justify** your prediction.



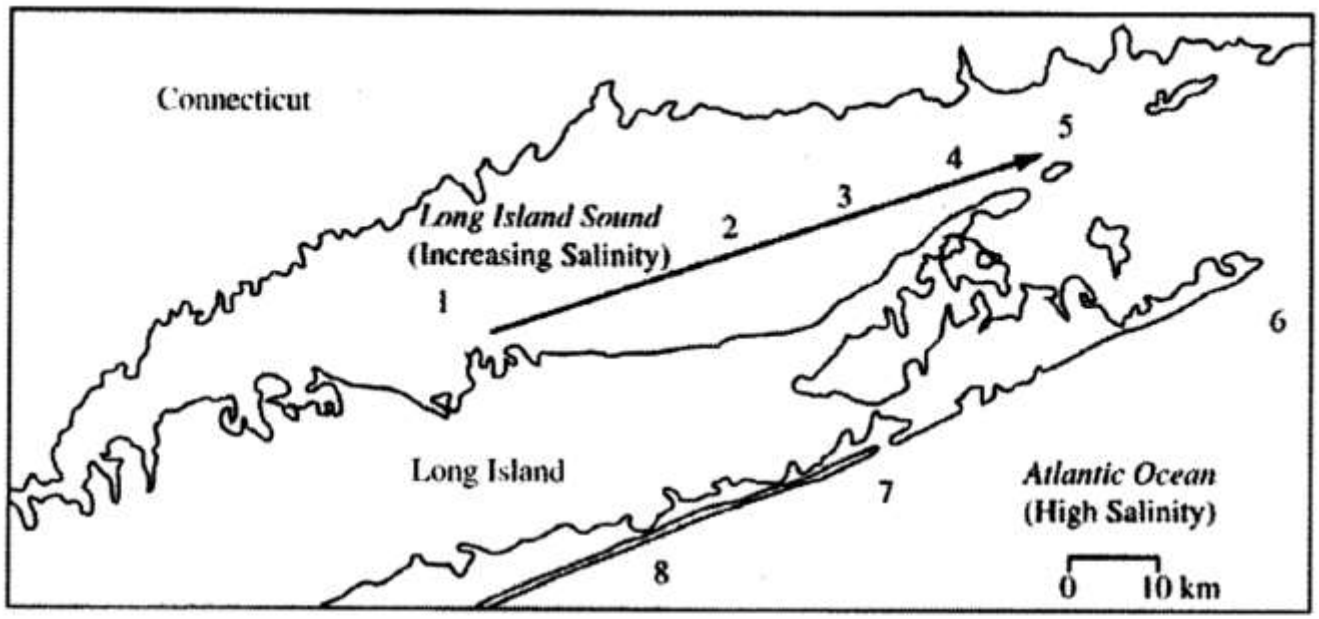


Figure 1. Sampling sites of marine mussels at various locations (1–8) in Long Island Sound and the Atlantic Ocean

TABLE 1. PERCENT OF INDIVIDUALS POSSESSING lap^{94} ALLELE

	Long Island Sound					Atlantic Ocean		
Site	1	2	3	4	5	6	7	8
lap^{94} frequency (%)	13	16	25	37	55	59	59	59
Salinity	Low →				High	High		

Leucine aminopeptidases (LAPs) are found in all living organisms and have been associated with the response of the marine mussel, *Mytilus edulis*, to changes in salinity. LAPs are enzymes that remove N-terminal amino acids from proteins and release the free amino acids into the cytosol. To investigate the evolution of LAPs in wild populations of *M. edulis*, researchers sampled adult mussels from several different locations along a part of the northeast coast of the United States, as shown in Figure 1. The researchers then determined the percent of individuals possessing a particular *lap* allele, lap^{94}, in mussels from each sample site (table 1).

8.

a. **Explain** the likely mechanism by which LAPs maintain homeostasis in the mussels.

b. **Describe** a feedback pathway that supports your proposed mechanism of homeostasis.

c. **Describe** the gene frequency trend observed for Long Island South and **propose an explanation** for the trend.